Blue Whiting Acoustic Survey Cruise Report, Spring 2007

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1 Introduction

Acoustic surveys on the blue whiting (*Micromesistius poutassou*) stock in the north east Atlantic have been carried out since the early 1970s by the Institute of Marine Research (IMR), Norway. In the early 1980s a coordinated acoustic survey approach was adopted, with both Russia and Norway participating to estimate the size of this migratory stock within its key spawning grounds. Since 2004, the coordinated survey program has expanded and now includes vessels from the Netherlands, Faroes and Ireland in addition to those from the Russian Federation and Norway.

Due to the highly migratory nature of the stock, a large geographical area has to be surveyed. Spawning takes place from January through to April, with a peak time between mid-March and early April. Consequently acoustic surveys are routinely carried out during the peak spawning period within known geographic confines. To facilitate a more coordinated spatio-temporal approach to this spawning stock survey participating countries meet annually to discuss survey methods and define target areas at the ICES led Planning Group of Northern Pelagic Ecosystem Surveys (PGNAPES).

Data from the annual spawning stock abundance survey (March/April), juvenile surveys (May) and commercial landings data are presented annually at the ICES led Northern Pelagic and Blue Whiting Fisheries Working Group (WGNPBW). Ultimately, combined data inputs into the management and catch advice for this cross boundary stock.

The 2007 survey was part of an International collaborative survey using the vessels RV "*Celtic Explorer"* (Marine Institute, Ireland), RV *"Atlantida"* (AtlantNIRO, Russian Federation), RV "*Tridens*" (IMARES, Netherlands) and the RV "*Magnus Heinason*" (FRS, Faroes) and the FV *"Eros"* (IMR commercial charter). The total combined area coverage in 2007 extended from the Faroe Islands in the north (61.30°N) to south of Ireland (50.30°N), with east -west extension from 5°-19° W. Combined area coverage included shelf break areas (>200m) and large bathymetric features including the Porcupine, Rockall and Hatton Banks.
The Irish component of the survey was made up of transects covering 2,624 nmi (nautical miles) covering the north Porcupine area, the eastern and western fringes of the Rockall Bank and the western slopes of the Hatton Bank. This survey represents the 4th survey in the Irish time series.

2 Materials and Methods

2.1 Scientific Personnel

Name	Organisation	Role
Ciaran O'Donnell	MI-FSS	Scientist in Charge
Eugene Mullins	MI-FSS	Acoustics & Deck Sci
Graham Johnston	MI-FSS	Acoustics
Susan Beattie	MI-FSS	Acoustics
Mikko Heino	IMR	Acoustics
Valantine Anthonypillai	IMR	Biologist
Jan Jenson	DFU	Biologist
Jenny Ullgren	NUIG	Oceanography

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic data on spawning and post spawning aggregations of blue whiting (*Micromesistius poutassou*) along the northern migration pathway from key spawning areas in target sub areas 1 and 2b (PGNAPES defined)

- Age stratified estimate of relative abundance and biomass of blue whiting (*Micromesistius poutassou*) within the survey area (ICES Divisions VIa-b)

- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of survey stock

- Collect physical oceanography data as horizontal and vertical profiles from a deployed sensor array.

2.2.2 Area of operation

The spring 2007 survey covered the area to the west of the British Isles (Figure 1), starting off the west coast of Ireland at the shelf break and progressing northwards to the Hebrides. Westward extension reached out to the 18°W, taking in the eastern and western flanks of the Rockall Bank and eastern slopes of the Hatton Bank. The survey began in the south and worked in a northerly progression following migration pathways of blue whiting.

The survey was carried out in continuity from south to north with no scheduled or unforeseen disruptions. The cruise track was modified on route to take into account gaps in total area coverage left by other participating countries vessels (the Netherlands and Russian Federation) due to unforeseen circumstances or poor weather and to ensure an even distribution of effort across core target areas.

2.2.3 Survey design

A parallel transect design was adopted with transects running perpendicular to the lines of bathymetry where possible. Offshore, transects extended to the 18°W. Transect spacing was set at 30nmi and maintained throughout the survey.

In total, the survey accounted for 2,624nmi, with 2,184nmi of integrateable acoustic transect data collected. Survey design and methodology is pre-determined by participating countries following methods laid out in the PGNAPES survey protocol.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FSS on previous surveys (O'Donnell *et al.,* 2004). The settings used on the *Celtic Explorer* acoustic array are shown in Table 1.

The acoustic data were collected using the Simrad ER60 scientific echosounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3m below the vessels hull or 8.8m below the sea surface. Three other operating frequencies were used during the survey (18, 120 and 200Khz) for trace recognition purposes, with the 38KHz data used solely to generate the abundance estimate.

Whilst on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect provi ding "silent cruising" as compared to normal operations (Anon, 2002). Cruising speed is maintained at a maximum of 10 Kts (knots) where possible. During fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

Calibration of the ER60 array was carried out in Killary Harbour, Co. Galway on the 28th March prior to starting the cruise track. The ER60 was last calibrated in October 2006 (O'Donnell *et al,* 2006b). Due to problems centring the target reference sphere only 3 out of 4 frequencies were calibrated (18, 38 & 120KHz). However, the results from the 38KHz frequency calibration were well within the expected range. A calibration report for the 38KHz transducer is shown in Table 1.

2.3.3 Inter-vessel calibration

The RV "*Celtic Explorer*" carried out an acoustic and trawl sampling intercalibration with the Faroese vessel the RV "*Magnus Heinason*" on the 6th of April.

During an acoustic intercalibration, firstly an area of blue whiting abundance was located. Vessels steaming to a pre-determined site are often able to highlight at area of interest with relative ease. The characteristics of a focus area include high-density isolated schools and in clear and open water away from the commercial fleet, if possible. The lead vessel is chosen and runs a course over the afore mentioned schools, commonly in the order of 10 to 20 nmi, with the trail vessel following at a distance of 0.5nmi and a bearing of 5° off the lead vessels starboard quarter, to avoid bubble attenuation from the propeller of the lead vessel. The lead vessel then communicates the start point at which the first nautical mile data logging point begins. Once the lead vessel is through the main area of interest logging is stopped and communicated to the trail vessel. Roles can then be reversed, if desired, with the lead vessels switch places running over the same area again. Total NASC values per 100m depth layer and NASC values allocated to blue whiting, after echogram scrutinisation, were summed per 1nmi interval and transmitted between vessels for analysis.

Once complete, trawls are undertaken on schools encountered with the aim of sampling the same schools. Data on length, weight, sex, maturity and age are then compared between samples.

2.3.4 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys (Table 1). The "RAW files" were logged via a continuous Ethernet connection as "EK5" files to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on DVD. Sonar Data's Echoview® Echolog (Version 3.2) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each target area. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up onto the vessels server every 24 hrs and scrutinised using Echoview. Partitioning of data into the above categories was largely subjective and was viewed by a scientist experienced in viewing echograms.

The "EK5" files were imported into Echoview for post-processing. The echograms were divided into transects. . Echo integration was performed on regions defined by enclosing selecting marks or scatter that belonged to one of the target species categories. The echograms were analysed at a threshold of -70 dB and where necessary plankton were filtered out by thresholding at –65 dB.

Echograms were scrutinised into one of the following categories:
a). Blue whiting, b). mesopelagic fish c). plankton, d).pelagic fish including mackerel, herring and horse mackerel occurring on the shelf edge.
Selection criteria are based upon behavioural, including diurnal migrations and habitat preference of each category.

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 70m in length (LOA) and a fishing circle of 768m was employed during the survey (Figure 12). Mesh size in the wings was 12.5m through to 20mm in the cod-end. The net was fished with a vertical mouth opening of approximately 50m, which was observed using a cable linked "BEL Reeson" netsonde (50 kHz). The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the blue whiting were weighed as a component of the catch. Age, length, weight, sex, stomach fullness and maturity data were recorded for individual blue whiting within a random 50 fish sample from each trawl haul with a further 100 random length and weight measurements were also taken. All blue whiting were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals. No bottom trawl gear was used during this survey.

2.3.7 Oceanographic data collection

Oceanographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a Seabird 911 sampler from 1m subsurface to 1000m where depth allowed or to within 20m of the bottom on the dedicated hydrographic transect running along the 57.30°N Figure 7).

2.3.8 Marine mammal and seabird observations

No marine mammal or seabird counts were undertaken during this years survey.

2.4 Analysis methods

2.4.1 Echogram partitioning and abundance estimates

The recordings of area back scattering strength (NASC) per nautical mile were averaged over five nautical miles, and the allocation of area backscattering strengths to species was made by comparison of the appearance of the echo recordings to trawl catches.

The allocation of NASC (Nautical Area Scattering Coefficient) values to blue whiting and other acoustic targets was based on the composition of the trawl catches and the appearance of the echotraces. To estimate the abundance, the allocated NASC values were averaged for ICES statistical rectangles (1° latitude by 2° longitude). For each statistical area, the unit area density of fish ($?_A$) in number per square nautical mile ($N*nm^{-2}$) was calculated using standard equations (Foote et al. 1987, Toresen *et al*. 1998).

For blue whiting a TS= 21.8 log(L) – 72.8 dB was applied.

To estimate the total abundance of fish, the unit area abundance for each statistical rectangle was multiplied by the number of square nautical miles in each statistical square and then summed for all statistical rectangle within defined sub areas and for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical rectangle and then sum all squares within defined sub areas and the total area.

The scrutinized acoustic data from the participating vessels were reported to the Marine Institute, Bergen, to produce combined assessments of the blue whiting in accordance with PGNAPES agreements.

Acoustic, biological and oceanographic data are submitted to PGNAPES for inclusion into a dedicated survey database.

3 Results

3.1 Blue whiting abundance and distribution

A total of 18 directed trawls were carried out over the course of the survey (Figure 1, Table 2). Of this, all contained blue whiting as the dominant species both by weight and numbers. The second most represented species, by weight, was dealfish (*Trachipterus arcticus*) (Table 2) and was represented in over 72% of valid trawl samples. Dealfish were evident in all trawls carried out. However, these mainly represented individuals caught in the forward larger meshes of the net and therefore not in the valid catch sample. Lanternfish, *Myctophidae sp.* occurred in 88% of hauls, and juvenile mackerel, *Scomber scombrus* in 28%. Overall, some 36 species were identified from trawl samples (Table 6).

3.1.2 Blue whiting biomass and abundance

Sub area	TSN (millions)	SSN (Millions)	TSB ('000t)	SSB ('000t)
N Porcupine	2873	2873	26	263
Hebrides	37877	37811	3622	3619
Rockall	7997	7997	843	843
Total	**48746**	**48681**	**4728**	**4725**
			4.73mt	**4.73mt**

A full breakdown of the survey stock structure is presented by distribution, age, length, biomass, abundance and area in Tables 3, 4 & 5 and Figures 2 & 4.

3.1.3 Blue whiting distribution

Blue whiting were distributed throughout the survey area, with the bulk distributed close to or along shelf break areas and along offshore banks and features (Figure 2). Shelf break areas, to the west of Scotland in the Hebrides sub area, yielded the highest concentration of registrations observed during the survey. In particular, the area to the west of St Kilda (ICES rectangle 5708) produced the highest values recorded during the survey with an individual school NASC of 43,330 m² /nmi². Overall, the area had the greatest mean NASC per nmi² of 9747 (Table 3 & 4). This is consistent with expected results at this time in this core area. This area was also the focus of the bulk of commercial fishing activity within the EU zone observed during the survey with vessels from Norway, Netherlands and Poland.

Blue whiting distribution in open ocean areas was lower when compared with the shelf break areas. Some medium density schools were recorded in open water in the southern end of the survey as a continuation of schools extending out from the shelf break to the north of the Porcupine north sub area. The Porcupine north sub area yielded a relatively small contribution to the overall total biomass. This can be attributed to the low overall coverage of the area and the late timing at which the survey passed through this region. The bulk of the stock being located further north at this time.

No blue whiting were detected in the area to the southeast of Rockall or from Rockall east along the 56°N line until the near shelf area was reached in the east. Distribution was light and patchy running further north until the Anton Dohrn seamount. Medium to high-density registrations were recorded continuously east from Anton Dohrn to the continental shelf break.

The area to the west of 14°W, Rockall sub area, contained the highest registrations in the northern area (north Rockall and southeast Hatton Banks), Figure 2, Tables 3 & 4. This area was also the focus of commercial fishing activity in the international zone by vessels from Russian Federation and the Faores. The southern extent of this area yielded little blue whiting biomass with very low registrations recorded overall.

3.1.4 Blue whiting stock structure

In total 900 blue whiting were aged, 2700 length measurements and 2700 weights were taken. Overall length distribution ranged from 16.5 cm to 39.0cm, with a modal length of 27.0 cm (Figure 4). Mean length in the Rockall area was 28.6 cm. Mean length in the Hebrides sub area was 27.5 cm. Mean length for the north Porcupine area was 27.0cm (Table 4).

Mean weight in the Rockall area was 105.4 g. Mean weight in the Hebrides sub area was 95.61 g and north Porcupine was 91.6 g (Table 4). Overall the fish from the north Porcupine area were smaller and lighter than those in the other sub areas. Indeed, samples from the Rockall area, although only contributing a relatively small amount (17.9%) to the TSB, were found to have the largest mean length and greatest mean weight of samples taken.

Haul 18 (Hebrides sub area) was different to the other hauls, with the smallest fish recorded during the survey (16.5cm) and 5 immature (Stage 1, of a 7 point scale) fish, the only haul where these were found possibly due to being close proximity to the shelf-edge.

In general, all hauls had rather similar length and age compositions with mean length in the range 26.8–28.3cm and mean age in the range 4.1–5.6 years.

Most (61%) blue whiting were spent (Stage 7), but a large amount (38%) were still spawning (stage 6). More males (51%) than females (28%) were spawning. Virgin fish were found in only one haul (Haul 18). The sex ratio was 50/50 throughout the survey.

Dominant ages were 4 and 5 year olds belonging to the 2003 and 2002-year classes respectively (Table 5). The age structure showed that the fish from the Rockall area were slightly older than the Hebrides area. Blue Whiting from the Porcupine sub-area were dominated (52%) by four-year-old fish.

3.2 Oceanography

3.2.1 Physical oceanography

Hydrographic data were collected using a SBE-911 CTD. Some problems with the CTD's conductivity sensor occurred during some early stations. After station 9 the sensor was replaced with a spare. A total of 28 CTD stations were completed during the survey (Figure 5), including the shallow CTD cast during calibration in Killary Harbour (Stn 0), which is not taken into account in the following description of the oceanographic conditions. The station spacing was generally roughly 60 nm (2° longitude, 1° latitude grid) and to a maximum depth of 1000 m as agreed at PGNAPES 2006. A full depth dedicated oceanographic transect was carried out in the Rockall Trough at the latitude of the Anton Dohrn seamount, where stations were only 12.8 nm apart and profiled to the full depth (stopping at ~20m above the seabed). The transect was completed in two parts, stations 11-16 from east to west on the 3-4 April and stations 17-20 from west to east on the 5th April.

In the southeastern part of the survey area (north Porcupine Bank sub area), the water column was generally well mixed down to depths of >600m, due to the deep winter mixing, which is common in the Rockall Trough. Further north the winter mixed layer was less deep, although relatively well-mixed conditions down to near 500m were found at some stations on the eastern part of the Anton Dohrn transect. A south-north section along 12°N showed higher temperature and salinity in the upper 600m south of about 57°N where a sharp transition to cooler, fresher water took place (Figure 6 a, b).

The warmest and most saline upper layer water was found in the south and west of the survey area, at about 55°-56°N in the central Rockall Trough stretching up along the eastern flank of Rockall Plateau (Figure 7 a, b). A sharp front northeast of Rockall Bank, between stations 23 and 24, separated the overall warmer and more saline water in the Rockall Trough from the distinctly cooler and fresher water over the Rockall-Hatton Banks. Between Rockall and Hatton Banks there was a further step in salinity and temperature, as the coolest and freshest water throughout the upper 600m was found at the two northwesternmost stations. Station 27 in the northwestern corner was the only station where the hydrographic properties fell outside of the Eastern North Atlantic Water (ENAW) envelope, showing the influence of fresher water masses from the west.

The temperature and salinity distributions at 10m and 200m were similar (unsurprising given the winter mixed conditions) but cool fresh water from the northwest extended slightly further eastward on the 58° 30'N section at the 200m level (Figure 8 a, b). In contrast to the shallower depth levels, at 400m depth and below the most saline and warm water north of 55°N was found on the eastern side of Rockall Trough (Figure 9 and 10 a, b). At the western side of the Trough, the water at 400-600m depth was cool and fresh, similar to the values found north of Rockall. Relatively cool and fresh water was also found at an isolated station at the eastern side, at the Hebrides Terrace Seamount, at all depths except the near-surface level.

Over the western flank of Anton Dohrn seamount, the temperature and salinity was slightly elevated (see horizontal plots, Figure 6-11), reflected in the sharply sloping contours of salinity and temperature west of the seamount (Figure. 11 a, b). The water in the upper 600m eastwards of Anton Dohrn was in general warmer and more saline than at the western end of the transect. The Rockall Current (or secondary branch of the Shelf Edge Current) that brings relatively warm and saline water northward across the Rockall Trough generally passes west of Anton Dohrn to re-join the Shelf Edge Current at about 58°-59°N (New and Smythe-Wright, 2001). A preliminary calculation of geostrophic current across the Anton Dohrn transect yielded a northward current core over the western flank of the seamount, centred between 11° 30' and 12°W.

3.2 Inter-vessel calibration

The *Celtic Explorer* carried out a calibration exercise with the Faroese vessel "*Magnus Heinason*" on the 9th April. This exercise was carried out in an area to the southeast of the Rosemary Bank (Point 13 on Figure 2). The exercise was carried out at night in relatively calm wind and swell conditions.

A single 25nmi transect was used to determined acoustic recordings and a comparative tow was carried out on localised schools to determine catch efficiency of trawl gear.
Overall, the *Magnus Heinason* recorded acoustic densities some 19% higher than the *Explorer*. However, this maybe a consequence of spatial heterogeneity due to vessel spacing among recorded schools as opposed to acoustic data recording capabilities.

Comparative trawling over the 60 minutes at the same depths showed variation in both bulk catch and length composition. The mean length of individuals from the *Explorer* was larger than those taken by the *Magnus Heinason.* This would suggest the *Explorer* is more efficient at capturing larger individuals. Again though, spatial heterogeneity should be considered.

A full analysis of the intercalibration results carried out by Mikko Heino (IMR) is presented Appendix 1.

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey was a great success. Survey aims were achieved and indeed exceeded. Good weather dominated overall and no time was lost due to poor weather or mechanical failure. This allowed for comprehensive trawling throughout the survey confines, underpinned with extensive oceanographic coverage, including a dedicated full depth hydrographic transect crossing the Anton Dohrn seamount (57°30N). The cruise track was run in continuity with all target areas covered without the need to leave the cruise track due to the effects of weather induced data degradation.

The original cruise track was extended on two occasions to ensure even geographical coverage throughout core survey areas. In the south, the *Celtic Explorer* cruise track was extended south from the 56°N to the 54°30N to take into account the area that the *Tridens* could not sufficiently cover due to prolonged poor weather. Further north, the Explorer's cruise track was again adjusted this time to the west covering the western Rockall to western Hatton Banks (14°-18°W) that were not sufficiently covered by the *Atlantida* due to mechanical failure.

During the survey some deep blue whiting layers were observed in excess of 750m. Observations on schools at 500m are most common. The RV Tridens also observed deep schools during her survey earlier in the season and further south around the Porcupine Bank. Deep schools are not unknown and have been recorded in the past, particularly during the *Johan Hjort* survey in 2001.

An inter-vessel calibration (acoustic and trawl gear) was carried out with the *Magnus Heinason*. This represents the third vessel the Explorer has inter-calibrated with during this survey program, the others being the IMR vessels *Johan Hjort* and the *G.O. Sars.*
During the survey the conductivity cell on the Seabird-911CTD unit had to be replacement due to intermittent data recording. The new cell had not been used before and so has not been calibrated, so data should be treated with a degree of caution. In future in may be prudent to bring a salinity meter or take water samples to cross reference salinity readings from the CTD unit as a quality control method.

4.2 Conclusions

The biomass of blue whiting recorded during the course of the survey, although distributed widely, is lower than would have been expected especially from the core area of the Hebrides. Overall, the density of individual schools was lower than in previous years and was dominated by areas of medium to low-density schools interspersed with smaller high-density schools close to the shelf edge. Some of these variations may be attributed to the slightly later timing of this years survey and the high proportion of spent individuals in trawl samples as compared to previous years. However, the Irish survey program has no time series in one particular target area so direct comparisons are difficult.

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Table 1 Survey settings and calibration report for the Simrad ER 60 echosounder. Blue whiting acoustic survey, March-April 2007.

Reference Target:			
TS	-33.50 dB	Min. Distance	10.00 m
TS Deviation	9.5 dB	Max. Distance	17.00 m
Transducer: ES38B Serial No. 30227			
Frequency	38000 Hz	Beamtype	Split
Gain	25.55 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.67 deg	Along. Beam Angle	6.39 deg
Athw. Offset Angle	0.03 deg	Along. Offset Angl	0.04 deg
SaCorrection	-0.65 dB	Depth	5.00 m
Transceiver: GPT 38 kHz 1 ES38B			
Pulse Duration	1.024 ms	Sample Interval	0.191 m
Power	2000 W	Receiver Bandwidth	2.43 kHz
Sounder Type:			
EK60 Version 2.1.1			
TS Detection:			
Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %
Environment:			
Absorption Coeff.	9.9 dB/km	Sound Velocity	1488.5 m/s
Beam Model results:			
Transducer Gain =	25.82 dB	SaCorrection =	-0.70 dB
Athw. Beam Angle =	7.18 deg	Along. Beam Angle =	7.10 deg
Athw. Offset Angle =	-0.03 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:

RMS = 0.10 dB
Max = 0.22 dB No. = 36 Athw. = 3.3 deg Along = 2.5 deg
Min = -0.36 dB No. = 1 Athw. = 4.5 deg Along = -0.7 deg

Data deviation from polynomial model:

RMS = 0.06 dB
Max = 0.18 dB No. = 136 Athw. = -2.1 deg Along = 3.4 deg
Min = -0.18 dB No. = 159 Athw. = -2.1 deg Along = -1.4 deg

Table 2. Catch composition, time and location of trawl hauls. Blue whiting acoustic survey, March-April 2007.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Blue Whiting %	Mackerel %	Meso %	Dealfish %	Others %
1	30.03.07	55 31.92	09 41.91	19:35	870	500	600	98.8	0.8	0.1		0.4
2	31.03.07	55 32.29	10 45.13	03:26	>2000	470	250	99.3		0.7		
3	01.04.07	56 01.76	10 18.19	09:07	2200	500	200	99.8		0.1		0.1
4	01.04.07	56 02.05	9 28.78	14:47	991	350-500	1000	99.5				0.5
5	02.04.07	56 32.04	13 49.61	17:08	1200	500	100	70.0		2.5	25.8	1.7
6	03.04.07	56 58.01	10 44.33	08:56	2250	500	150	77.9		0.3	21.5	0.3
7	03.04.07	56 58.13	9 32.77	16:00	1800	500	150	91.5			2.3	6.2
8	04.04.07	57 27.91	09 42.41	01:20	1000	450=550	300	94.6	0.1		5.2	0.1
9	04.04.07	57 27.65	10 30.52	11:12	2219	550-580	75	51.5		0.5	46.3	1.7
10	04.04.07	57 28.43	11 17.07	01:40	771	450-520	96	65.7		1.0	32.3	1.1
11	05.04.07	57 27.81	12 52.22	03:00	780-1200	420-520	1500	68.2			31.8	
12	06.04.07	57 58.10	09 37.42	17:00	721	420-500	200	98.7	1.1	0.1		0.1
13	07.04.07	57 58.10	09 37.42	01:00	>2000	420-520	250	88.8		0.7	9.4	1.1
14	07.04.07	58 21.27	09 26.47	12:57	>2000	500	300	98.8	0.4	0.5		0.2
15	08.04.07	58 27.90	12 12.58	06:15	1800	450-600	4000	100.0				
16	11.04.07	58 58.70	16 54.75	06:47	1000	500-550	50	82.8		7.7		9.5
17	11.04.07	58 58.10	15 24.85	15:45	1150	550-600	120	62.0		1.1	34.6	2.3
18	12.04.07	58 58.57	07 43.70	20:51	1000	350-500	450	89.1	2.1		8.5	

Note: “Others” was used to represent mesopelagic fish and non-fish species occurring in the catch. Fishing time relates to time spent fishing once gear had reached required target depth.

Table 3. Breakdown of abundance estimate by sub area, including trawl haul allocation. Blue whiting acoustic survey, March-April 2007.

Rectangle	NASC $m^2/n.m^2$	Area $n.mile^2$	Trawl haul(s) #	length cm	Density coeff. $1.488 * 10^6 * L^{-2.18}$	Abundance $N * 10^6$	weight gram	Biomass 1000 tonnes
5412	224	2224	1&2	27.00	1127.794378	561.84	91.60	51.46
5410	785	2610	1&2	27.00	1127.794378	2310.68	91.60	211.66
Porc N					**Sub area total**	**2872.52**		**263.12**
5510	518	3437.5	1&2	27.00	1127.794378	2008.18	91.60	183.95
5610	526	3844	3&6	28.40	1010.11065	2042.39	98.30	200.77
5710	1676	3600	9&10	28.20	1025.79334	6189.23	97.70	604.69
5810	209	3600	13	27.40	1092.211398	821.78	96.80	79.55
5808	1623	2724	14	27.50	1083.571712	4790.53	98.90	473.78
5708	9747	1380	8&12	27.20	1109.794889	14927.70	93.00	1388.28
5608	2316	1680	4&7	27.40	1092.211398	4249.66	101.20	430.07
5508	2974	750	1&2	27.00	1127.794378	2515.55	91.60	230.42
5806	1510	190	18	26.70	1155.602257	331.54	90.80	30.10
Hebrides					**Sub area total**	**37876.55**		**3621.60**
5512	29	896	1&2	27.00	1127.794378	29.30	91.60	2.68
5612	195	2301	5	28.10	1033.768165	463.85	102.80	47.68
5712	465	2429	11	27.30	1100.951939	1243.51	94.10	117.01
5812	676	3438.5	15	28.20	1025.79334	2384.38	125.30	298.76
5814	902	3270	16&17	29.30	943.6947063	2783.47	97.20	270.55
5714	121	2280	16&17	29.30	943.6947063	260.35	97.20	25.31
5816	222	3520	16&17	29.30	943.6947063	737.44	97.20	71.68
5716	129	778	16&17	29.30	943.6947063	94.71	97.20	9.21
Rockall					**Sub area total**	**7997.00**		**842.89**
					Grand total	**48746.07**		**4727.62**

Table 4. Breakdown of abundance and biomass by survey sub area as used during analysis. Blue whiting survey, March-April 2007.

Sub area	Area nm^s	Abundance (Mils)			Biomass ('000s t)			Mean Length	Mean weight	Density
		Immature	Mature	Total	Immature	Mature	Total	(cm)	(g)	t/nmi2
Porcupine N	4834	0	2872.52	2872.52	0	263.12	263.12	27	91.6	54.43
Hebrides	21206	65.23	37811.32	37876.55	2.4	36192	3621.6	27.46	95.61	170.78
Rockall	18913	0	7997	7997	0	842.89	842.89	28.58	105.4	44.57
Total	44953	65.23	48680.84	48746.07	2.4	4725.21	4727.6	83.04	292.61	269.78

Table 5. Aged stratified estimate of surveyed stock abundance and biomass. Blue whiting survey, March-April 2007.

Length	Age (years)										TSN	TSB	Mn Wt
(cm)	1	2	3	4	5	6	7	8	9	10	(Mils)	('000t)	(g)
16.5	2	0	0	0	0	0	0	0	0	0	2.2	0.1	24.5
17	0	0	0	0	0	0	0	0	0	0	0	0	0
17.5	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5	2	2	0	0	0	0	0	0	0	0	4.4	0.2	36.7
19	4	0	0	0	0	0	0	0	0	0	4.4	0.2	37
19.5	62	0	0	0	0	0	0	0	0	0	62.5	2.3	37.3
20	0	0	0	0	0	0	0	0	0	0	0	0	0
20.5	0	0	0	0	0	0	0	0	0	0	0	0	43.2
21	0	52	0	0	0	0	0	0	0	0	51.5	2.3	44.2
21.5	0	21	21	21	0	0	0	0	0	0	62.2	3.0	47.4
22	0	0	117	0	0	0	0	0	0	0	117.2	6.2	53.2
22.5	0	28	168	0	0	0	0	0	0	0	196.4	10.8	55.2
23	0	102	407	0	0	0	0	0	0	0	508.4	29.6	58.2
23.5	0	98	98	98	0	0	0	0	0	0	292.8	18.6	63.6
24	0	102	457	51	0	0	0	0	0	0	609.7	40.5	66.4
24.5	0	0	441	631	63	0	0	0	0	0	1135.0	79.6	70.1
25	0	59	997	763	176	0	0	0	0	0	1994.3	147.5	74.0
25.5	0	142	852	1704	284	71	71	0	0	0	3124.3	246.2	78.8
26	0	0	1270	2390	1344	224	75	0	0	0	5302.5	437.0	82.4
26.5	0	0	891	2261	1096	206	0	0	0	0	4452.7	383.2	86.1
27	0	0	632	3388	2297	804	0	0	0	0	7121.0	647.3	90.9
27.5	0	0	449	2358	1572	618	112	0	0	0	5109.2	484.7	94.9
28	0	0	540	1834	2266	755	54	54	0	0	5503.0	546.1	99.2
28.5	0	0	147	1031	1326	687	98	49	0	0	3338.6	350.6	105.0
29	0	0	0	596	1238	413	229	138	0	0	2614.3	286.5	109.6
29.5	0	0	48	388	533	630	145	97	0	0	1840.8	218.3	118.6
30	0	0	45	267	490	357	134	45	0	0	1337.1	163.8	122.5
30.5	0	0	57	172	343	286	57	0	0	0	914.9	121.2	132.4
31	0	0	0	78	352	196	157	78	0	0	861.1	121.3	140.8
31.5	0	0	43	87	130	87	173	87	0	0	607.1	86.6	142.6
32	0	0	0	80	159	80	80	80	0	0	477.6	75.6	158.3
32.5	0	0	0	0	25	76	50	50	25	0	226.6	37.0	163.1
33	0	0	0	33	33	33	17	17	17	17	166.3	30.0	180.7
33.5	0	0	18	18	18	18	35	88	18	0	210.0	41.6	198.3
34	0	0	0	0	18	37	37	0	18	0	110.4	22.7	205.2
34.5	0	0	0	0	25	50	50	0	0	0	125.6	27.4	218
35	0	0	0	0	17	17	33	50	17	17	150.6	32.8	217.6
35.5	0	0	0	0	29	0	0	0	0	0	28.8	6.8	234.5
36	0	0	0	0	0	0	3	0	0	0	3.1	0.8	242.7
36.5	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	5	0	0	0	0	5.5	1.2	224
37.5	0	0	0	0	0	53	0	0	0	0	52.9	12.6	239
38	0	0	0	0	14	0	0	0	0		14.2	3.9	278
38.5	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
39	0	0	0	0	0	7	0	0	0	0	6.8	1.7	254
TSN (Mils)	71.31	604.1	7697	18247	13849	5707	1611	831.4	94.44	33.36	**48746.08**	**4727.6**	
% Mature	0	100	100	100	100	100	100	100	100	100			
TSB ('000t)	2.437	31.04	585	1681	1424	639.2	219.3	126.2	14.59	5.422	**4727.6**		
SSB ('000t)	0	31.04	585	1681	1424	639.2	219.3	126.2	14.59	5.422	**4725.2**		
Mn Wt	34.17	51.38	76	92.1	102.8	112	136.1	151.8	154.5	162.5			
Mn L	18.75	22.92	25.81	27.15	28.26	29.26	30.71	31.62	31.75	34			

Table 6. Species occurrence from survey trawl stations. Blue whiting survey, March-April 2007.

Category	Common Name	Scientific Name	Occurrence
	Blue Whiting	*Micromesistius poutassou*	**18**
	Mackerel	*Scomber scombrus*	**5**
	Horse mackerel	*Trachurus trachurus*	**1**
Mesopelagics	Hatchet Fish (large)	*Argyropelecus olfersi*	**9**
	Hatchet Fish (small)	*Argyropelecus hemigymnus*	**4**
	Silver Pomfret	*Pterycombus brama*	
	Dealfish	*Trachipterus arcticus*	**13**
	None	*Diretmus argentus*	**1**
	Lantern fish	*Myctophidae*	**16**
	None	*Lampadena speculigera*	**1**
	Pearlside	*Maurolicus muelleri*	**7**
	Greater Argentine	*Argentina silus*	
	Greenland Argentine	*Nansenia groenlandica*	**9**
	Sloanes Viper fish	*Chauliodus sloani*	**4**
	Schnakenbeck's searsid	*Sagamichthys schnakenbecki*	**1**
	Alfonsino	*Beryx decadactylus*	**1**
	None	*Notolepis rissoi*	**4**
	Greater Pipefish	*Syngnathus acus*	**8**
	Shrimps	*Pandalidae*	**6**
	Scaly dragonfish	*Stomias boa*	**4**
	Blackfish	*Centrophagus niger*	**6**
	None	*Astronethus gemmifer*	**1**
	None	*Opisthoproctus soleatus*	**1**
	None	*Gonastoma elongatum*	**3**
	Bean's sawtoothed eel	*Serrivomer beani*	**1**
	Forgotten argentine	*Nansenia oblita*	**1**
	Balbo sabretooth	*Evermanella balbo*	**1**
	Bluntsnout smooth-head	*Xenodermichthys copei*	**1**
	None	*Scopelosaurus lepidus*	**1**
	None	*Echiostoma barbatum*	**1**
	Searsids	*Maulisia*	**2**
Demersal	Grey Gurnard	*Eutrigla gurnardus*	**2**
	Silvery Pout	*Gadiculus argentus*	
Squid	Lesser flying squid	*Todaropsis elbanae*	**3**
	Northern flying squid	*Todarodes sagittatus*	**4**
	Short finned squid	*Omnastrephidae*	**8**
		Total Number of Trawls	**18**

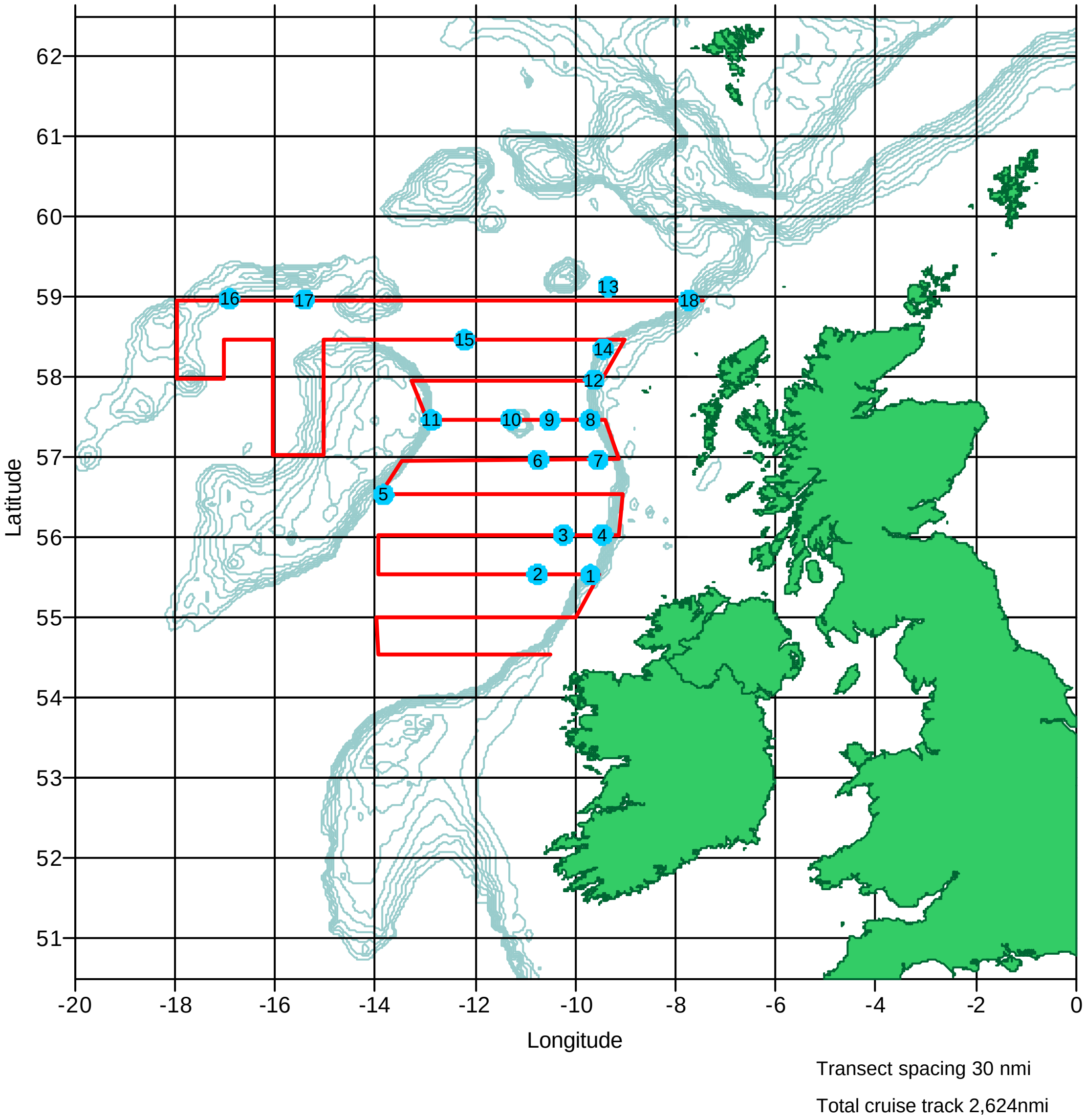


Figure 1. RV Celtic Explorer cruise track showing position of trawl stations as carried out during the blue whiting acoustic survey, March-April 2007. Note: Haul 13 was conducted off track during inter-calibration exercise with the RV "*Magnus Heinason*"

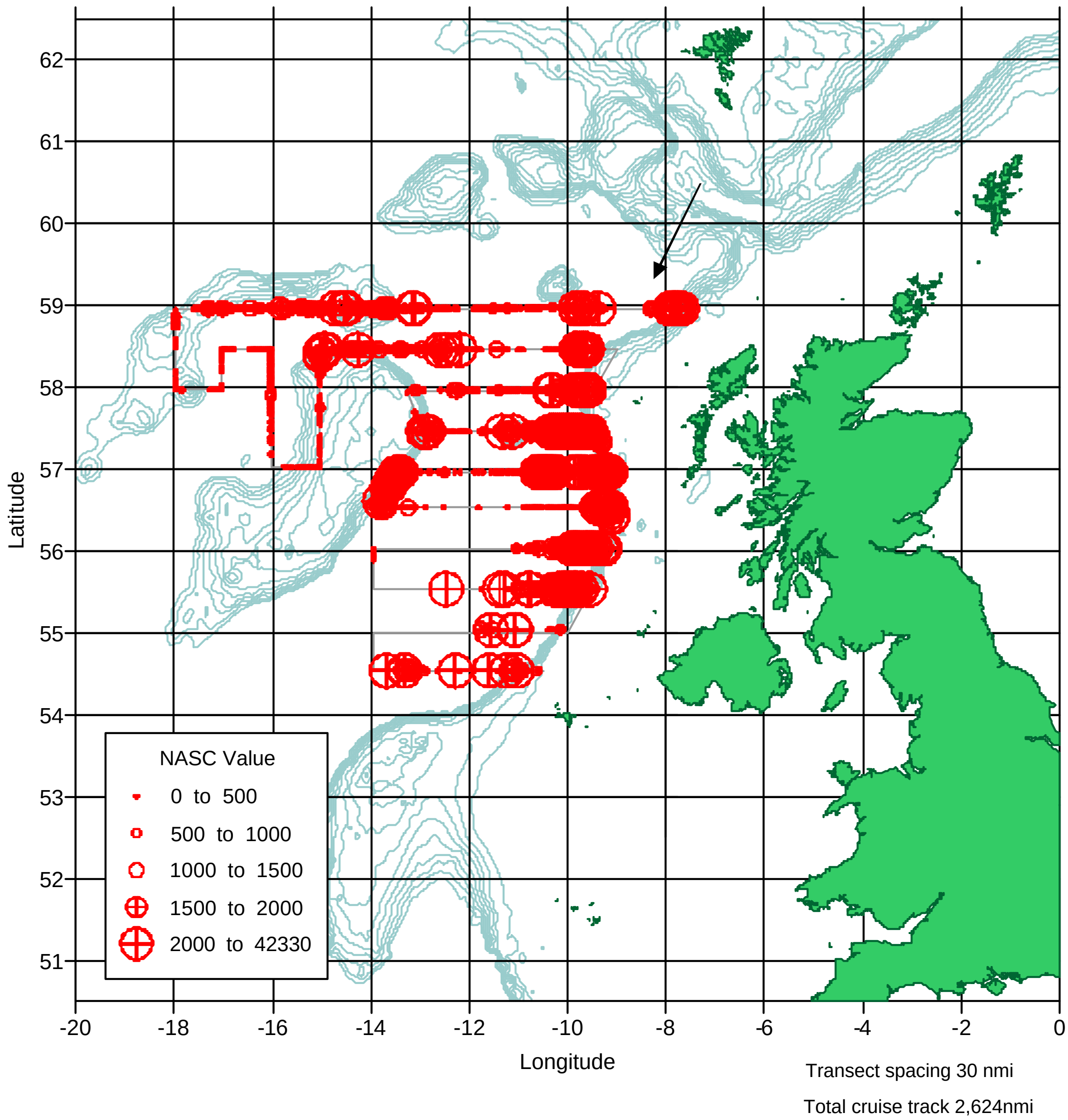
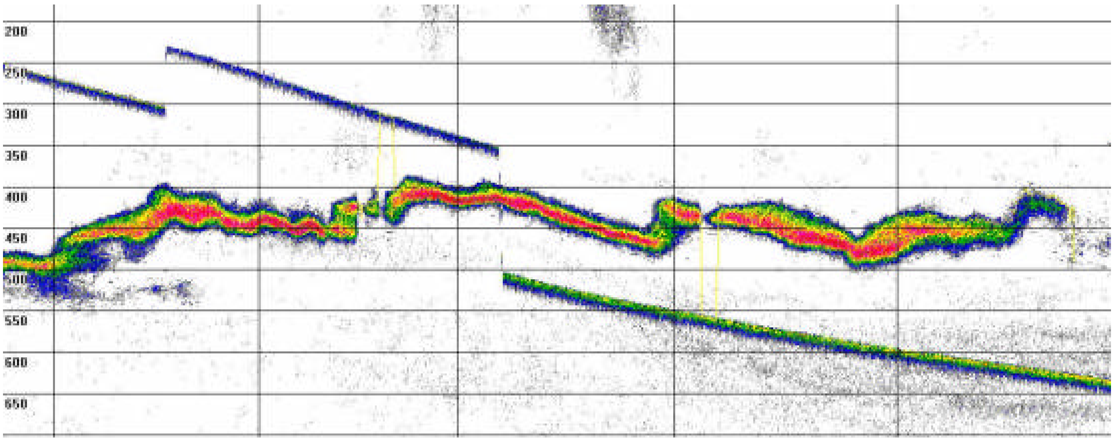
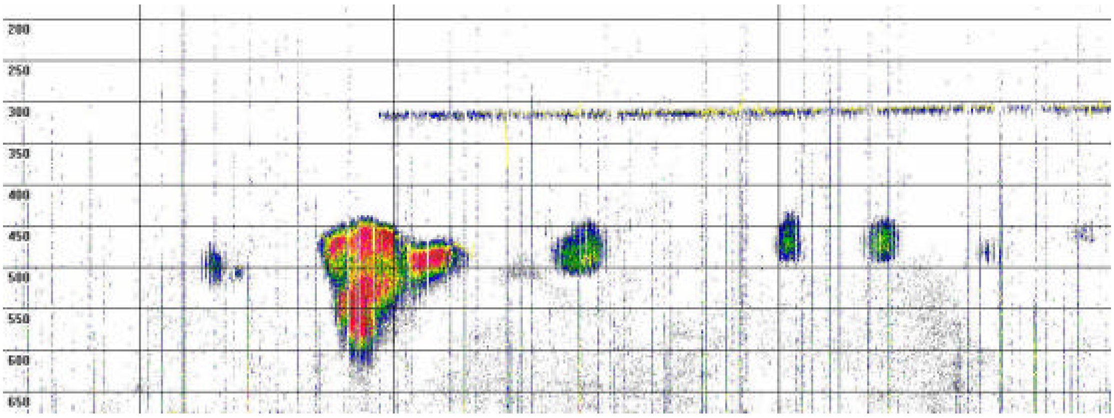


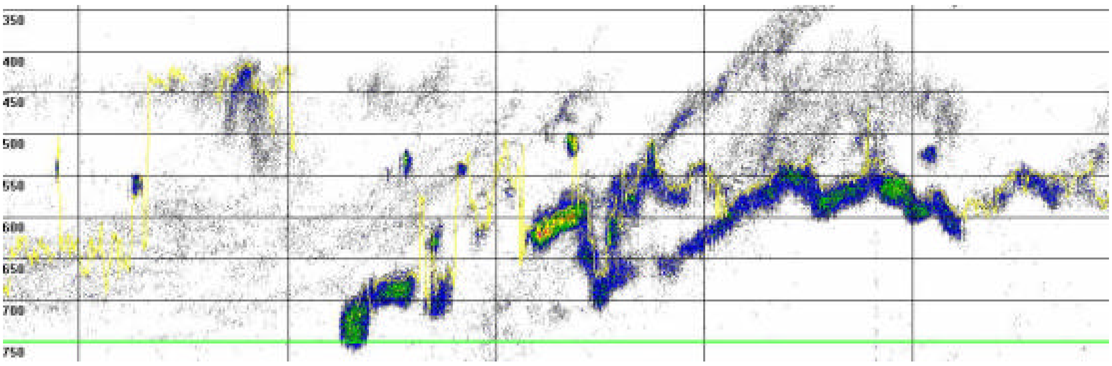
Figure 2. NASC distribution plot of blue whiting occurrence, circle size relative to NASC value. Blue whiting acoustic survey, March-April 2007.Note: Area indicated by arrow (top right) represents an area of data loss due to logging error and not zero blue whiting distribution.



a). *High-density echotraces of blue whiting recorded prior to* ***Haul 08*** *on* ***Transect 13*** *(57°30N & 09°55W). These recordings were some of the largest encountered during the survey. Vertical bands on echogram represent 1nmi (nautical mile) spacing and blue line extending from top left to bottom right is an artefact due to a secondary bottom echo.*



b). *Single large high-density school of blue whiting recorded prior to* ***Haul 15*** *(58°30N & 12°10W) on* ***Transect 17****. Note the depth range of the school, some 100m+. This school contained the highest proportion of larger individuals (up to 35.5cm and up to 9 years) sampled during the survey. Vertical striations on echogram represent weather-induced interference.*



c). *Deep schools of blue whiting as recorded on* ***Transect 3*** *(54°30N & 10°W). Appearance of deep schools appeared to be restricted to the southern and eastern extent of survey coverage. Vertical bands on echogram represent 1nmi spacing.*

Figures 3a-c. Blue whiting echotraces recorded on the ER60 echosounder with images captured from Echoview during the blue whiting acoustic survey, March 2007.

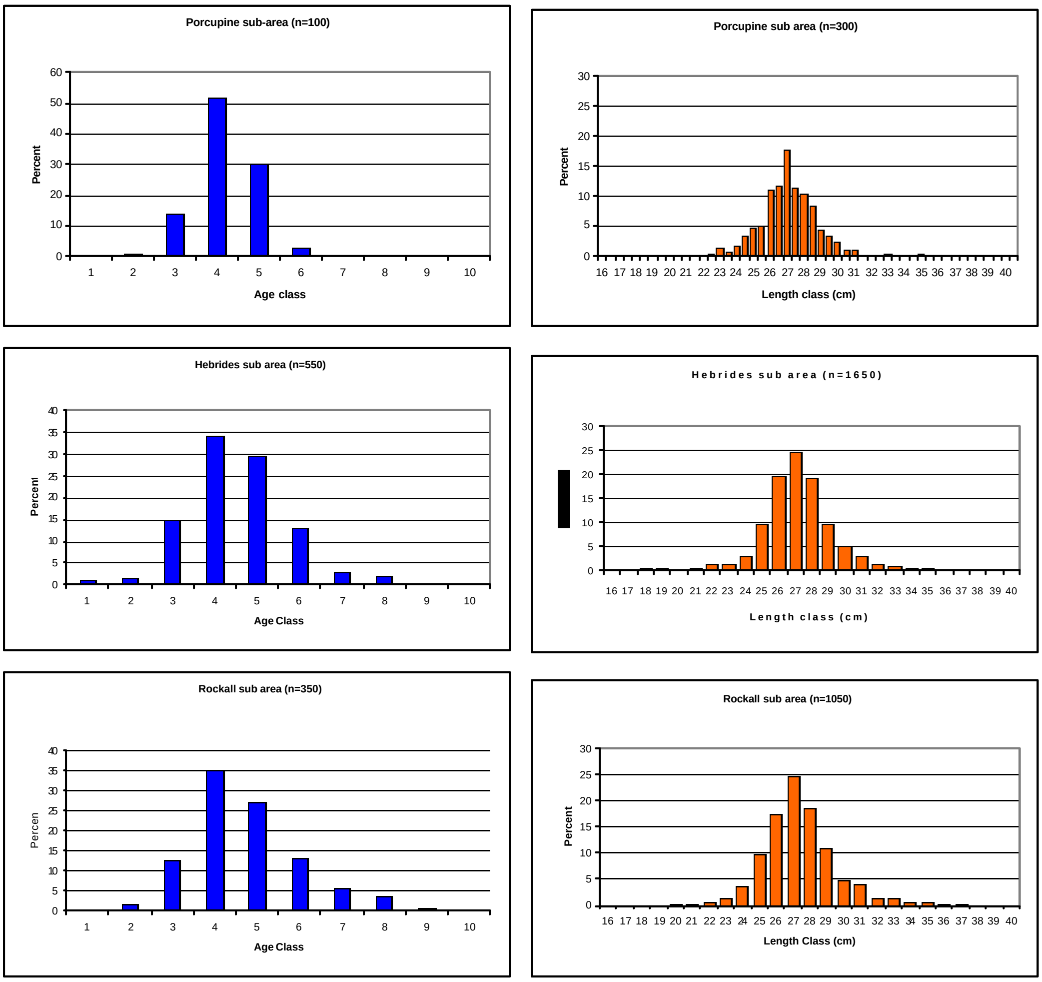


Figure 4. Age (left) and length (right) composition of blue whiting by main sub area. Blue whiting survey, March-April 2007.

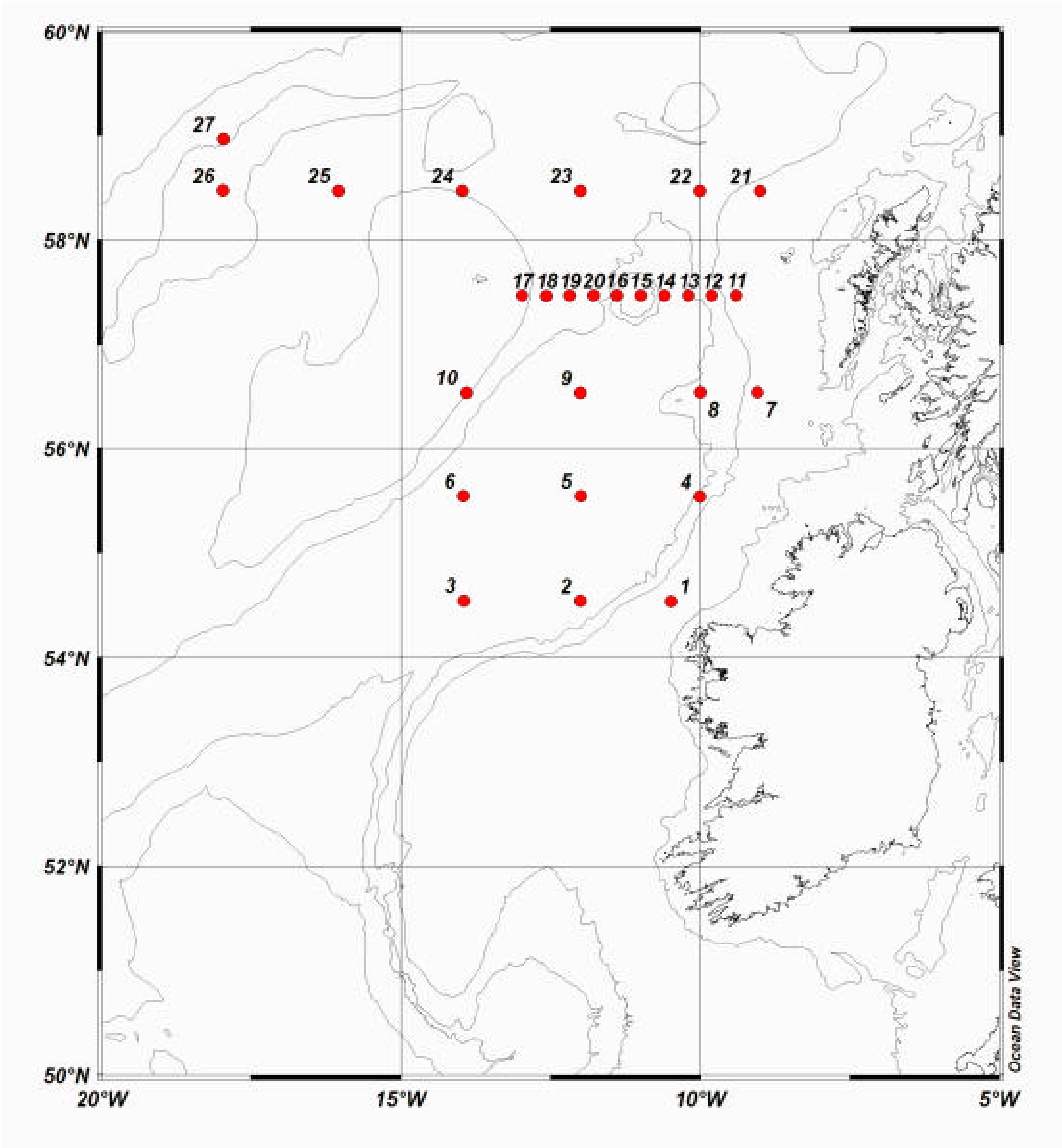


Figure 5. Oceanography stations completed (excluding shallow profile in Killary Harbour for ER60 calibration purposes). Bathymetry contour interval 1000m, with 100 m contour added. Blue whiting survey, March-April 2007.

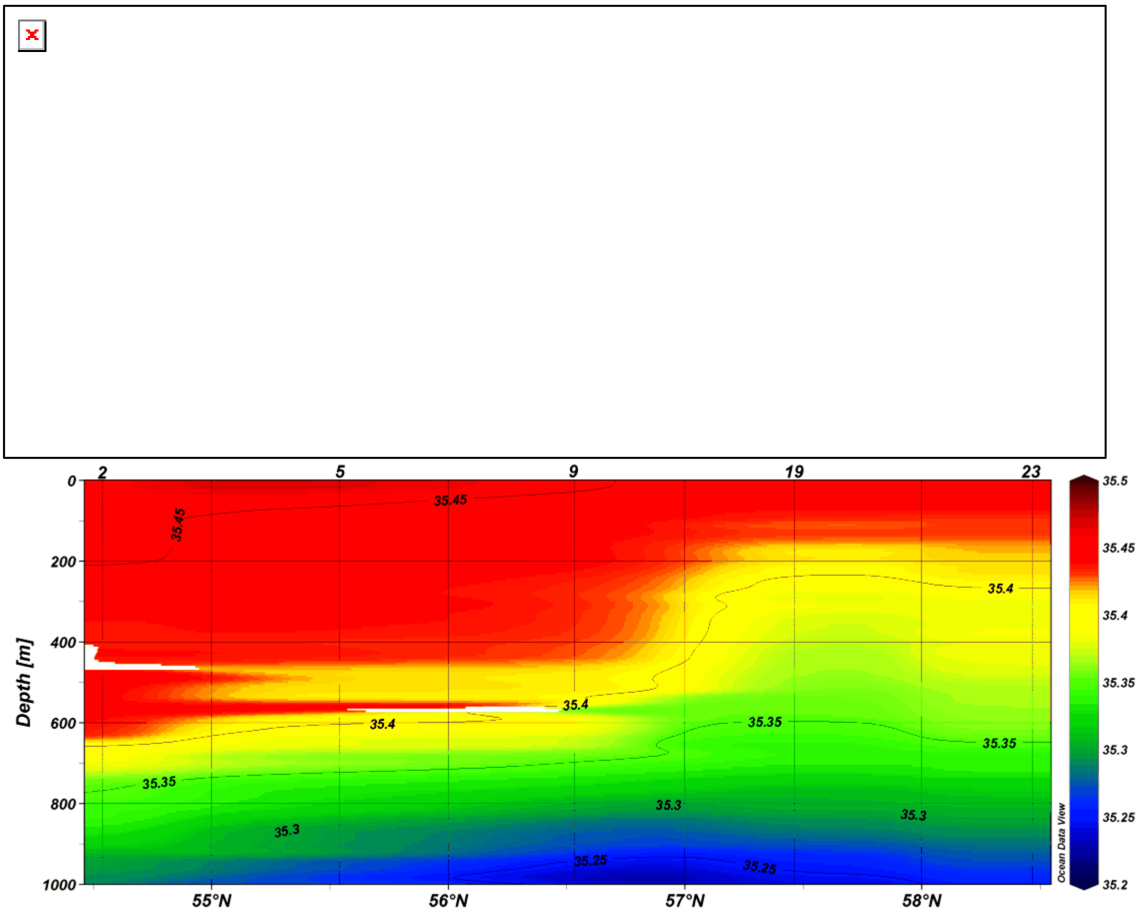


Figure 6. South-North section along 12°W, upper 1000 m only shown. Top panel: temperature, contour interval 0.5°C. Bottom: Salinity, contour interval 0.05. Some data gaps (white) due to CTD sensor problems. Blue whiting survey, March-April 2007.

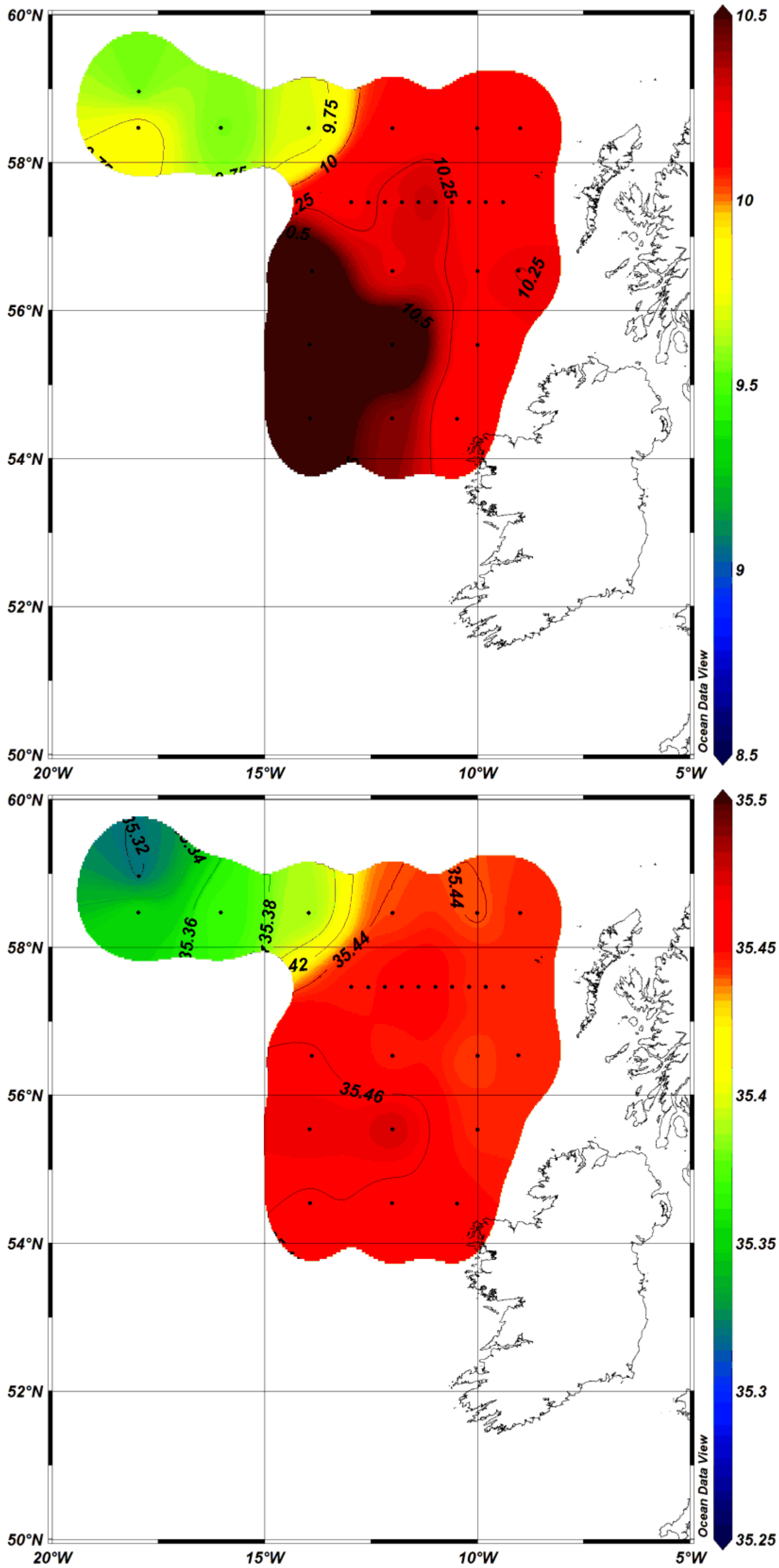


Figure 7. Horizontal distribution of temperature (top) and salinity (bottom) at 10 m depth. Blue whiting survey, March-April 2007.

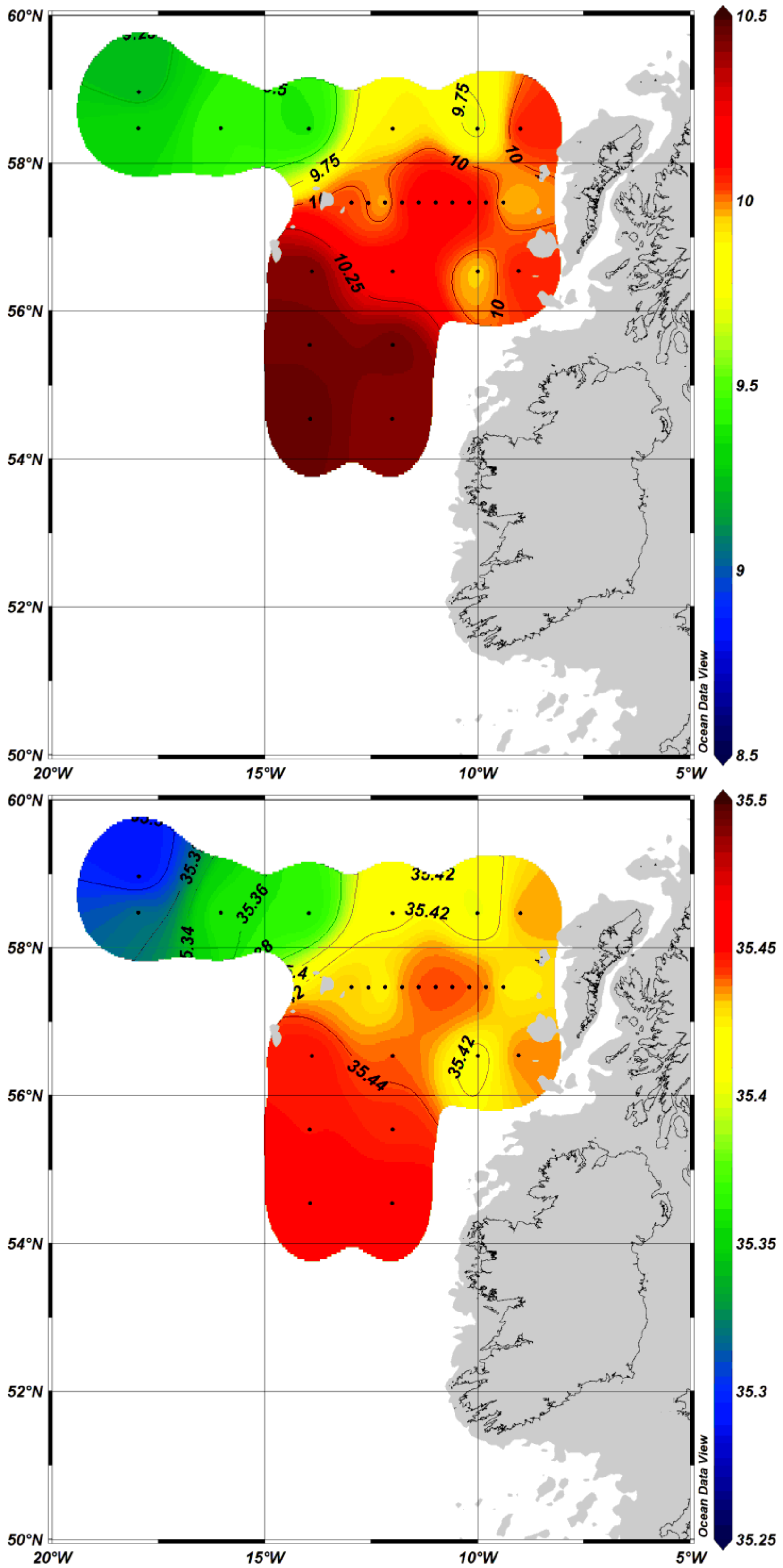


Figure 8. Horizontal distribution of temperature (top) and salinity (bottom) at 200 m. 100 m depth contour shaded grey. Blue whiting survey, March-April 2007.

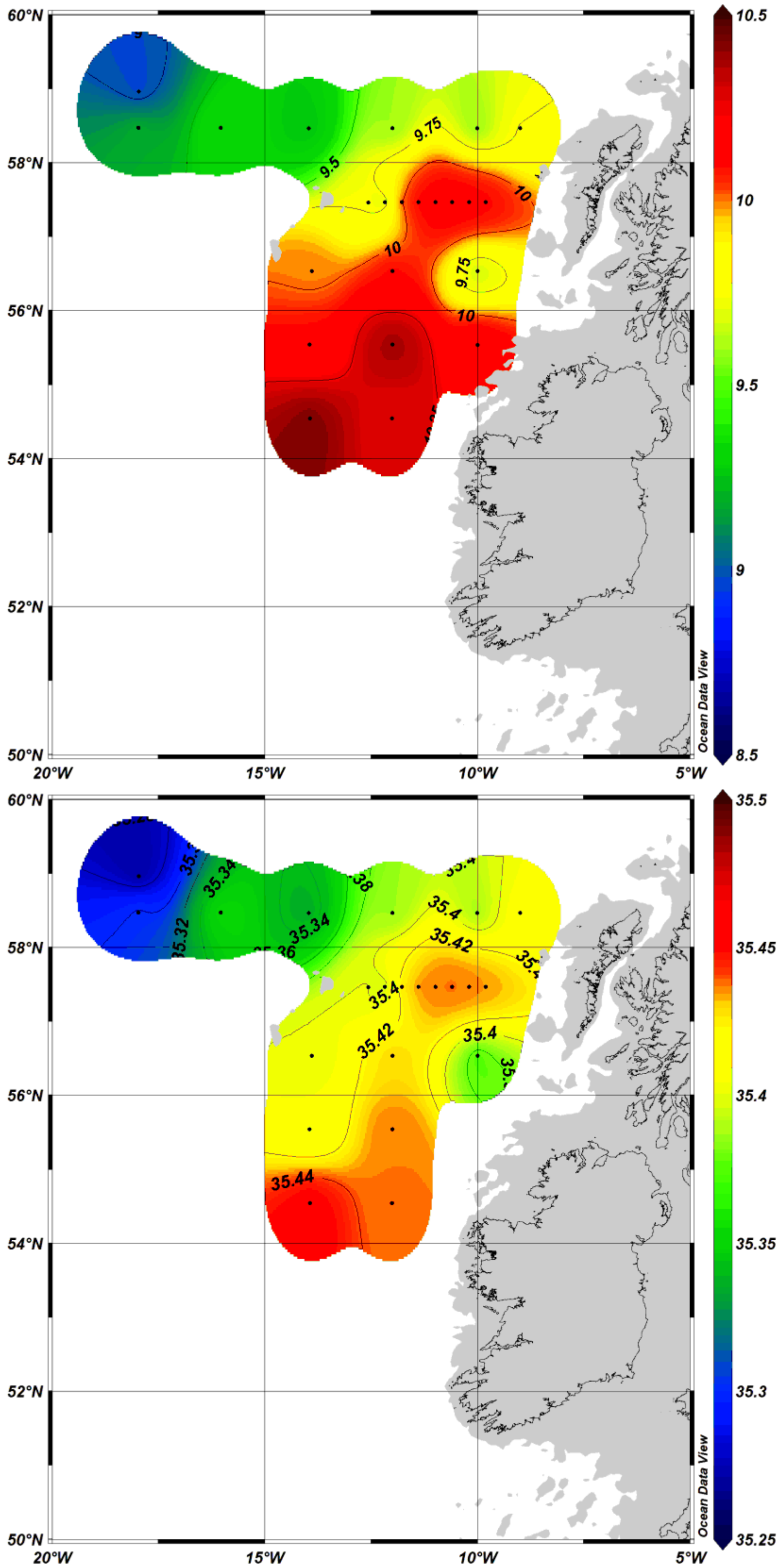


Figure 9. Horizontal distribution of temperature (top) and salinity (bottom) at 400 m depth. 100 m depth contour shaded. Blue whiting survey, March-April 2007.

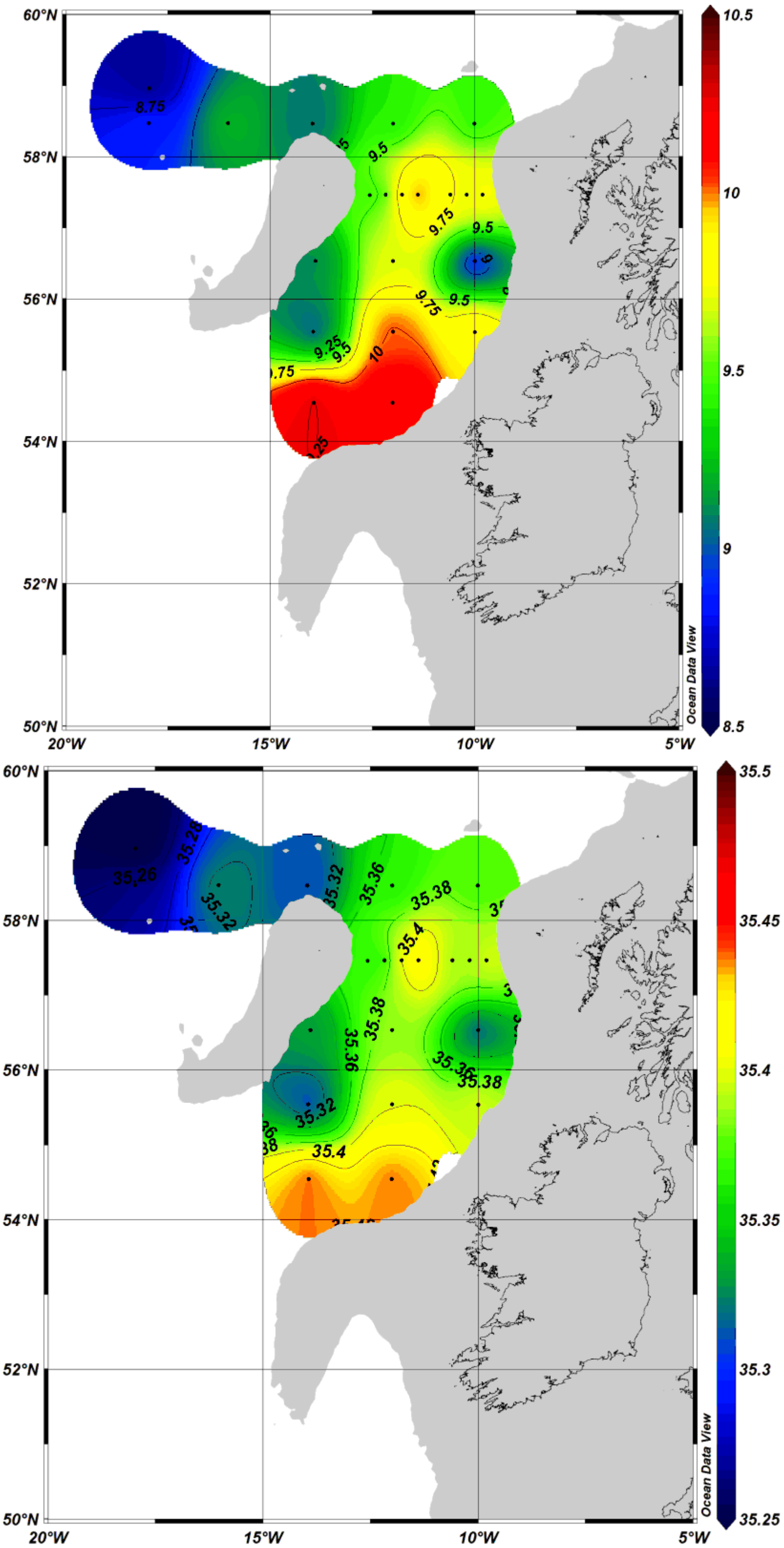


Figure 10. Horizontal distribution of temperature (top) and salinity (bottom) at 600 m depth. 500 m depth contour shaded grey. Blue whiting survey, March-April 2007.

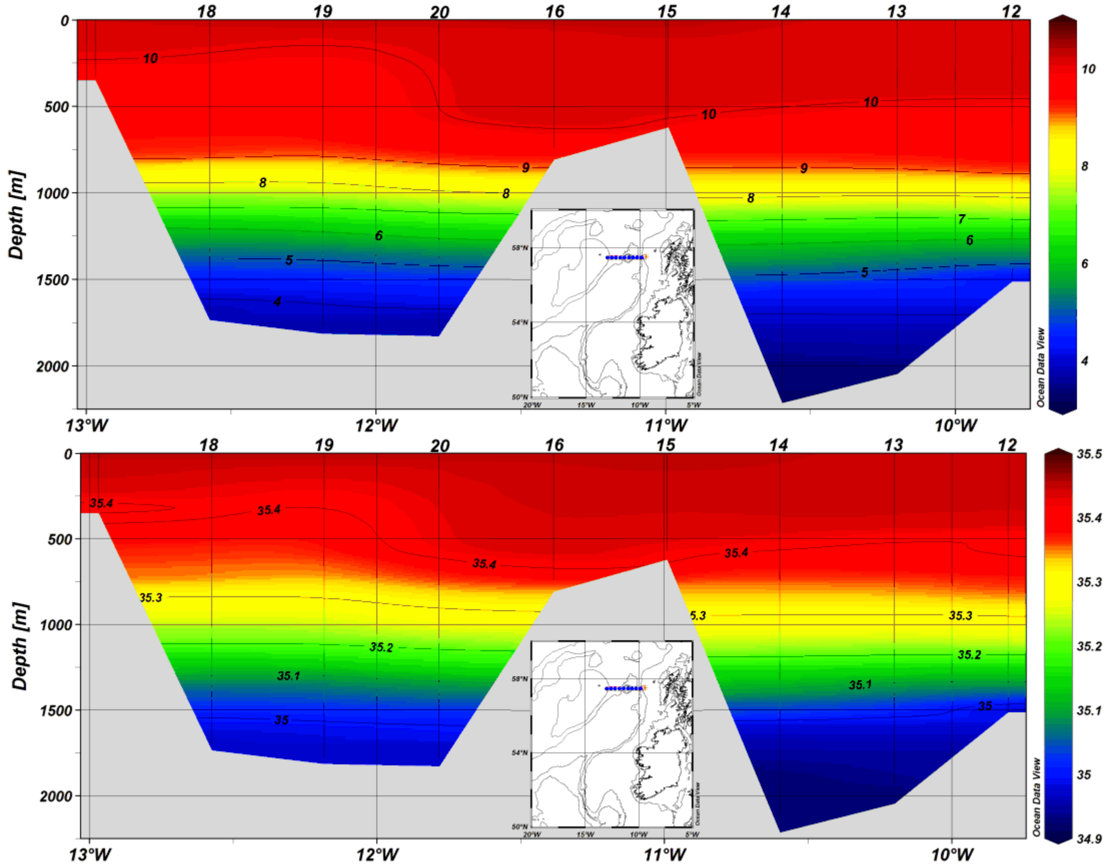
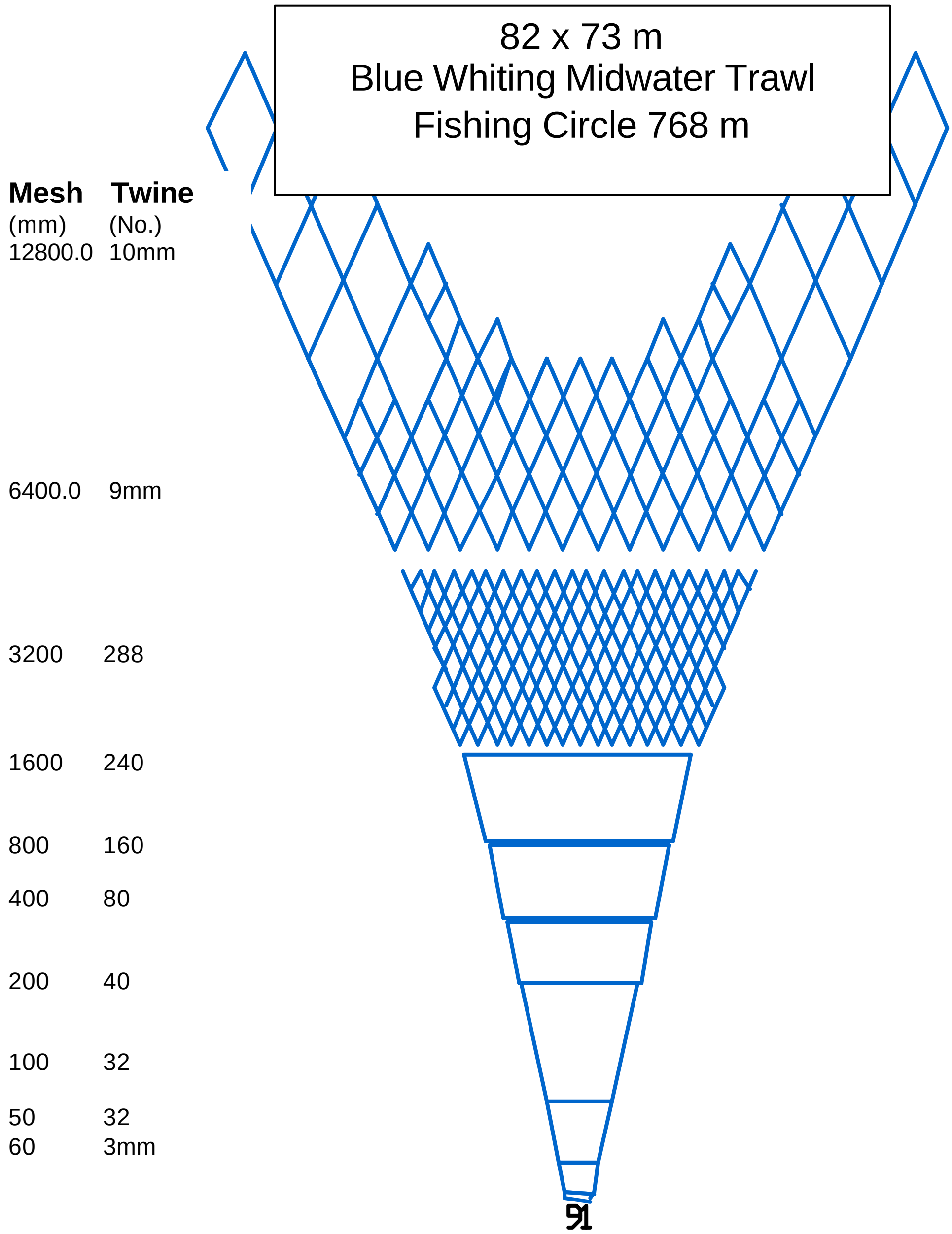


Figure 10. East-West section along 57° 30'N, across Anton Dohrn seamount (see small inset map). Note that the colour scales of temperature (top) and salinity (bottom) are different to the previous section and horizontal plots. Blue whiting survey, March-April 2007.



Net specifics	
Clump weights:	1000 Kg per side
Trawl doors:	Polyice pelagic 6m² (750Kg weight in air)
Bridle length:	80m
Door spread:	170m
Vertical net opening:	50m

Figure 12. Pelagic midwater trawl employed during the Blue whiting Acoustic Survey, March-April 2007.

Appendix 1

Intercalibration exercise between the RV Celtic Explorer and the RV Magnus Heinason

Acoustic inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason was conducted on April 7 between the Rosemary Bank and the Hebrides shelf break from about N59°05' W09°05' to N58°45' W08°45'. The weather was fairly favourable with moderate wind (18–20kt from WSW) and moderate swell (about 2 metres from W). The main acoustic features in the area were (1) up to 200 metres thick layer of blue whiting in depths between 400 and 600 metres that was strongest towards the end of the transect, (2) a layer of presumed macro-zooplankton from depth 300 metres downward, partly mixed with the blue whiting layer, and (3) plankton and mesopelagic fish, in the uppermost 200 metres.

The inter-calibration was the run over 25 nautical miles between 02:48-05:47 GMT. Vessels were cruising SSE at parallel courses, with the distance between the tracks being about 0.5 nm.

In the data analysis we focused on acoustic densities (s_A, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows acoustic densities recorded by the two vessels and allocated to blue whiting. The recordings show a fair qualitative agreement. Regression model suggests that intercept is not significantly different from zero. Regression forced through the origin has high coefficient of determination (R^2) and a slope that is significantly larger than one; the model suggests that Magnus Heinason records some 19% higher acoustic densities for blue whiting than Celtic Explorer. This is a rather large difference. Closer scrutiny of the echograms suggests that the difference can be traced to two sources. First, the echograms from Celtic Explorer showed sudden disappearances of blue whiting echoes for a range of about six nautical miles. These lasted for some tens of seconds at time, while other echoes (including the false bottom recording) were unchanged. The likely reason for this phenomenon is behavioural response (diving) to some vessel noise. This was not visible in recordings of Magnus Heinason. Second, echograms suggest that spatial heterogeneity was contributing to the different recordings. As the vessels were sailing 0.5 nm apart, this is entirely reasonable.

Before the acoustic inter-calibration, pelagic trawls of the two vessels were compared. Both vessels towed to the same direction at a distance of about 0.5 nm apart. Celtic Explorer towed for 60 minutes at depths of 420–520 metres and caught 222 kg of blue whiting. Magnus Heinason towed in the same depth for the same time and caught 170 kg of blue whiting.

As seen in Fig. 3, blue whiting in the catch of Celtic Explorer were larger in mean length (mean±sd length: 27.4±2.1 cm) compared to the blue whiting in the catch of Magnus Heinason (26.6±2.1cm). The difference in means was statistically significant ($p=0.0002$). Although spatial heterogeneity may contribute to the difference, the results suggest that Celtic Explorer is somewhat more efficient in capturing large blue whiting. The difference is similar to the difference recorded in inter-calibrations between Magnus Heinason and G. O. Sars in 2005–2006.

Table 1. Regression models for the full data. Intercept is estimated in the first regression, whereas regression through the origin is assumed in the latter one. The null hypothesis for t-tests on slope is that the slope is not different from one. Acoustic densities from Celtic Explorer are taken as the independent variable and those from Magnus Heinason as the dependent variable. n=25.

Model	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
Intercept estimated	Intercept	-176	189	-1.36	0.361	97.0
	Slope	1.220	0.044	5.01	<0.001	
Intercept=0	Slope	1.193	0.033	5.91	<0.001	98.2

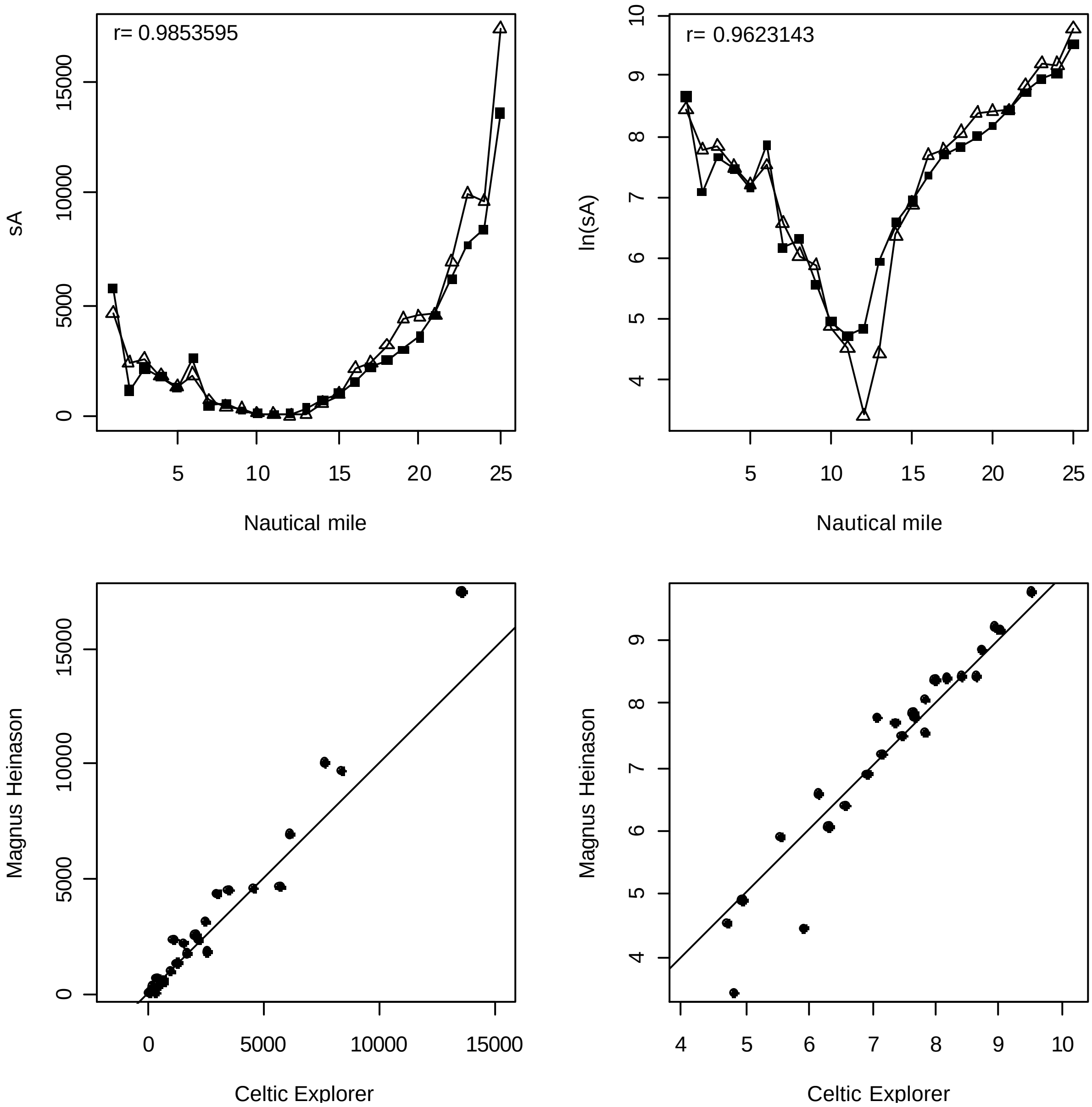


Figure 1. Comparison of blue whiting acoustic densities recorded by Magnus Heinason (open triangles) and Celtic Explorer (squares). The lower panels give same data as scatterplots. The diagonals are drawn as continuous lines.

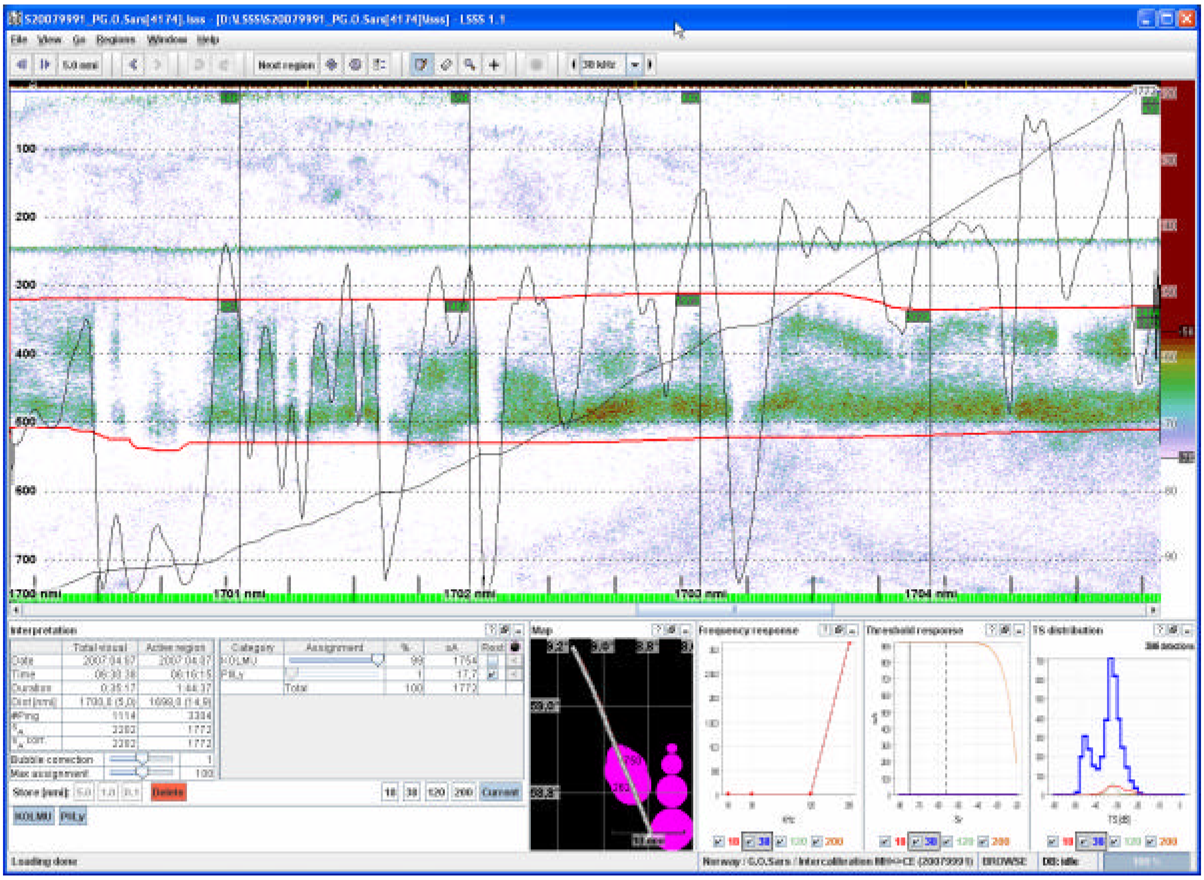


Figure 2. Echogram from Celtic Explorer showing intermittent dissappearance of blue whiting echoes. The same phenomenon was virtually absent in the recordings from Magnus Heinason.

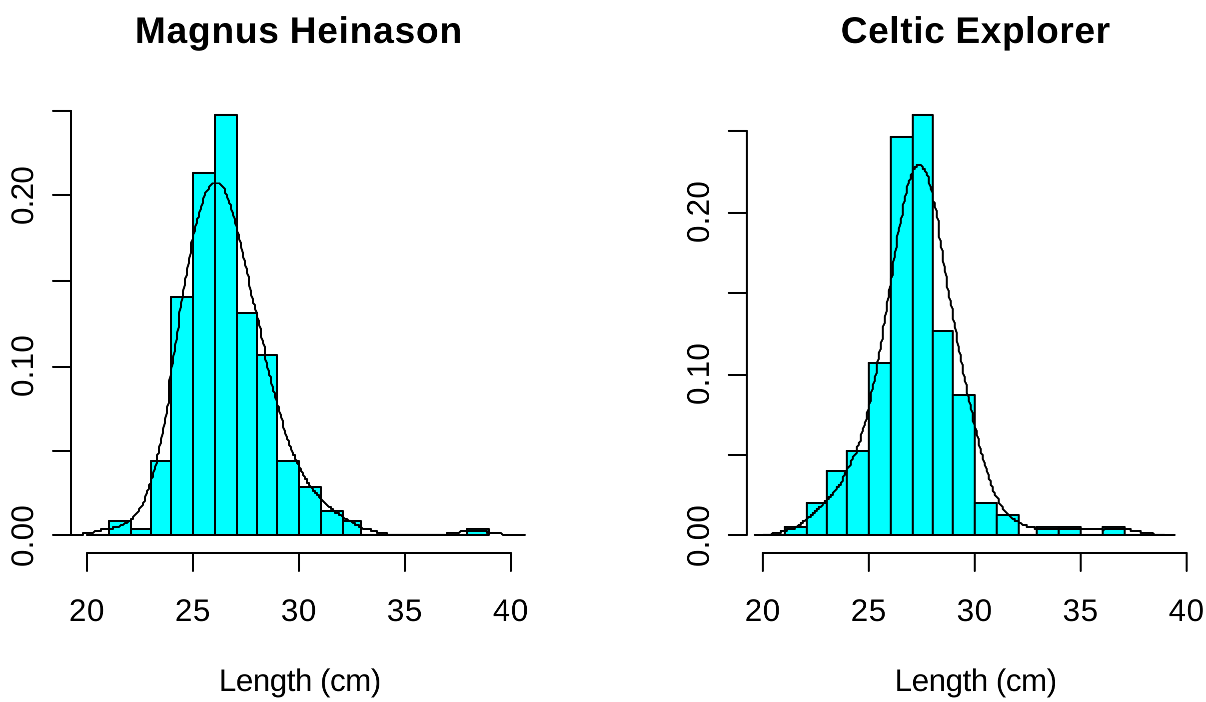


Figure 3. Length distributions from the trawls hauls by Magnus Heinason and Celtic Explorer. Smoothing is obtained by normal kernel density estimates